XL.—*On Spore-cases in Coals.*

By J. W. Dawson, LL.D., F.R.S.*

When I was in London last spring, Prof. Huxley was kind enough to show me some remarkably beautiful slices of coal mounted by his assistant, Mr. Newton, and showing with great distinctness multitudes of spore-cases and spores, some of them very well preserved. He further stated to me his belief that such material had been largely or mainly instrumental in the production of coal. At the time I declined to accept this conclusion, on the ground that the specimens probably represented layers of coal exceptionally rich in spore-cases, and that even in these specimens a large quantity of matter was present which long experience in the examination of coals enabled me to recognize as cortical or epidermal matter, which I had previously shown, by my examination of the coals of Nova Scotia, to be the principal ingredient in ordinary coal. I promised, however, on my return to Canada, to look over my series of preparations of coal, with a view to the occurrence of spore-cases, and also to make trial of the somewhat improved method of preparation employed by Mr. Newton. On my return I gave the results of my examination to Prof. Huxley in a letter quoted by him in the brilliant exposition of his observations and conclusions in the 'Contemporary Review' for November†, which will probably give a tone to the representations of popular writers on this subject for some time. While, however, admitting the great interest and importance of Prof. Huxley's observations, and prepared to contribute some additional illustrations of the occurrence of spore-cases in coal, I think it well to direct attention anew to the actual composition of the substance, as proved by its mode of occurrence, and illustrated by my own extensive series of observations on the coals of Nova Scotia and Cape Breton, including the series of eighty-one seams exposed at the South Joggins, the whole of which I have examined *in situ* and under the microscope.

The occurrence of bodies supposed to be spore-cases in coal is, as Prof. Huxley states, no new discovery, but in reality these may be said to be the first organisms recognized by any microscopic observer of coal—that is, if all the clear spots and annular bodies seen in slices of coal are really spore-cases. They were noticed by Morris as early as 1836, and they had been observed and described long before by Fleming in Scot-

* From 'Silliman's American Journal,' April 1871.

† In the quotation the word "cubical" has been substituted for "cortical."

land. Goeppert mentioned and figured them in his 'Treatise on Coal' in 1848. Balfour described them in 1859 as occurring in Scottish coals; and Quekett figured them in his account of the Torbane-Hill mineral in the same year. In 1855, the latter microscopist showed me in London slices exhibiting round bodies of this kind, very similar to those now described by Huxley; but at that time I regarded them as concretionary, though Prof. Quekett was disposed to consider them organic. Mr. Carruthers has summed up most of these facts in his account of his genus *Flemingites* in the 'Geological Magazine' for October 1865. The subject has also attracted the attention of microscopists in connexion with the Tasmanite or "white coal" of Tasmania, which is composed in great part of the spore-cases of ferns.

I suppose that the oldest spore-cases known are those described by Hooker from the Ludlow formation of the Upper Silurian; but these, if really spore-cases, are different in structure from those ordinarily found in the coal-formation, more especially in the great thickness of their walls, and I am not aware that they have anywhere been found in considerable quantities.

The oldest bed of spore-cases known to me is that at Kettle Point, Lake Huron. It is a bed of brown bituminous shale, burning with much flame, and, under a lens, is seen to be studded with flattened disk-like bodies, scarcely more than a hundredth of an inch in diameter, which under the microscope are found to be spore-cases, slightly papillate externally, and with a point of attachment on one side and a slit more or less elongated and gaping on the other (figs. 1, 2, 3). I have proposed

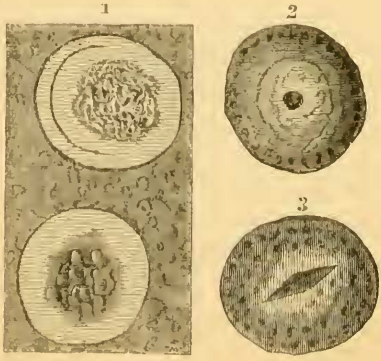


Fig. 1. Part of a slice of shale from Kettle Point, showing two spore-cases and remains of spores. Magn. 70 diams.
Figs. 2 & 3. Spore-cases from the same, as opaque objects. 70 diams.

for these bodies the name of *Sporangites huronensis*. When slices of the rock are made, its substance is seen to be filled with these bodies, which, viewed as transparent objects, appear yellow like amber, and show little structure, except that the walls can in some cases be distinguished from the internal cavity, and the latter may be seen to enclose patches of flocculent or granular matter. In the shale containing them there are also vast numbers of rounded translucent granules, which may be the escaped spores.

The bed at Kettle Point is stated in the Report of the Geological Survey to be from 12 to 14 feet in thickness; but to what degree either in its thickness or horizontal extent it retains the characters above described, I do not know. It belongs to the Upper Devonian, being supposed to be a representative of the Genesee slates of New York. It contains stems of *Calamites inornatus* and of a *Lepidodendron*, obscurely preserved, but apparently of the type of *L. Veltheimianum*, and possibly the same with *L. primævum* of Rogers. The spore-cases are not improbably those of this plant, or of the species *L. gaspianum*, which belongs to the same horizon, though not found at this locality. The occurrence of this bed is a remarkable evidence of the abundance of Lycopodiaceous trees, whose spores must have drifted in immense quantities in the winds, to form such a bed. It is to be observed, however, that this is not a bed of coal, but a bituminous shale, of brown colour, and with pale streak, no doubt accumulated in water, and even marine, since it contains *Spirophyton** and shells of *Lingula*. In this it agrees with the Australian Tasmanite, which, though composed in great part of spore-cases of ferns, is, as I am informed by Mr. Selwyn, an aqueous deposit, containing marine shells.

There is, however, one bed of true coal known in the Devonian of Eastern America, that of Tar Point, Gaspé; and it is curious to observe that this is not composed of spore-cases, but of successive thin layers of rhizomata and stems of *Psilophyton*, with occasional fragments of *Lepidodendron* and *Cyclostigma*. Rounded disks, which may be spore-cases, occur in it, but very rarely. In the bituminous shales associated with this coal the microscope shows amber-coloured flakes of irregular form; but these are easily ascertained to be portions of the epidermis of *Psilophyton*, or of the chitinous crusts of crustaceans which abound in these beds.

Ascending to the Lower Carboniferous (sub-Carboniferous), there are great quantities of rounded spore-cases of the size of

* The well-known *Cauda-galli* fucoid.

mustard-seeds (*Sporangites glabra* of my papers) in the rocks of Horton Bluff and Lower Horton, Nova Scotia. They are sometimes globular, and filled with pyrites of a granular texture, which perhaps represents the original cellular structure or the microspores; in other cases they are flattened, and constitute thin carbonaceous layers. They are, almost without doubt, the spore-cases of *Lepidodendron corrugatum*, which abounds in the same beds, and constitutes in one place a forest of erect stumps. I described them in a paper on the Lower Carboniferous of Nova Scotia, in the 'Proceedings of the Geological Society of London' for 1858, though not then aware of their true nature, which, however, was recognized by Dr. Hooker in some specimens which I had sent to London.

In my paper on the conditions of accumulation of Coal (Proc. Geol. Soc. London, May 1866), I proposed the name of *Sporangites* for these bodies, in consequence of the difficulty of referring them certainly to any generic forms. Carruthers had, in Oct. 1865, described a cone containing rounded spore-cases of not dissimilar type, under the name of *Flemingites*. In the paper above referred to, I stated that, out of eighty-one coals of the South-Joggins section examined by me, I recognized these bodies and other fruits or sporangia in only sixteen; and of these only four had the rounded Lycopodiaceous spore-cases similar to those of *Flemingites*. These are the following:—

1. Coal-group 12, of Division IV., has a bed of coal 1 foot thick, of which some layers are almost wholly composed of *Sporangites papillata*.

2. Coal-group 13, Div. IV., has in some layers great quantities of *Sporangites glabra*, especially in the shaly part of the coal.

3. In Coal-group 14, Div. IV., a shaly parting contains great numbers of similar sporangites.

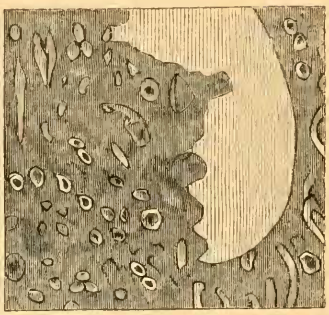
4. In coal-group 15 *a*, Div. IV., the shaly roof abounds in sporangites, but I did not observe them in the coal itself.

In addition to these cases, all of which, curiously enough, occur in one part of the section, and among the smaller coals, I have noted the occurrence of clear amber spots in several of the compact coals; but I did not regard these as certainly organic, suspecting them to be rather concretionary or segregative structures.

The great coal-beds of Pictou are, so far as my observation has extended, remarkably free from indications of spore-cases, and consist principally of cortical and ligneous tissues, with layers of finely comminuted vegetable matter. A layer of

cannel, however, from a bed near New Glasgow, has numerous flattened amber-coloured disks, which may be of this character. In those of Cape Breton, the yellow spore-case-like spots are much more abundant; but these coals I have less extensively examined than those of the mainland of Nova Scotia. Of American coals, the richest in spore-cases that I have seen is a specimen from Ohio, which contains many large spore-cases and vast numbers of more minute globular bodies, apparently macrospores. It quite equals in this respect some of the English coals referred to by Huxley (fig. 4). I have also a specimen of anthracite, from Pennsylvania, full of spore-cases, some of them retaining their round form, and filled with granular matter, which may represent the spores.

Fig. 4.



Part of a slice of Ohio coal, showing at one side a part of a large spore-case and numerous spores. Magn. 70 diams.

It is not improbable that sporangites, or bodies resembling them, may be found in most coals; but the facts above stated indicate that their occurrence is accidental rather than essential to coal-accumulation, and that they are more likely to have been abundant in shales and cannel coals deposited in ponds or in shallow waters in the vicinity of Lycopodiaceous forests than in the swampy or peaty deposits which constitute the ordinary coals. It is to be observed, however, that the conspicuous appearance which these bodies, and also the strips and fragments of epidermal tissue which resemble them in texture, present in slices of coal, may incline an observer not having large experience in the examination of coals to overrate their importance; and this, I think, has been done by most microscopists, especially those who have confined their attention to slices prepared by the lapidary. One must also bear in mind the danger arising from mistaking concretionary accumulations of bituminous matter for sporangia. In sections of the bituminous shales accompanying the Devonian coal above mentioned there are many rounded yellow spots, which, on examination, prove to be the spaces in the epidermis of *Psilophyton* through which the vessels passing to the leaves were emitted. To these considerations I would add the following, condensed from my paper above referred to, in which the whole question of the origin of coal is fully discussed* :—

* See also 'Acadian Geology,' 2nd edit. pp. 138, 461, 493.

1. The mineral charcoal, or "mother coal," is obviously woody tissue and fibres of bark, the structure of the varieties of which and the plants to which it probably belongs I have discussed in the paper above mentioned.

2. The coarser layers of coal show under the microscope a confused mass of fragments of vegetable matter belonging to various descriptions of plants, and including, but not usually largely, sporangites.

3. The more brilliant layers of the coal are seen, when separated by thin laminæ of clay, to have on their surfaces the markings of *Sigillariæ* and other trees, of which they evidently represent flattened specimens, or, rather, the bark of such specimens. Under the microscope, when their structures are preserved, these layers show cortical tissues more abundantly than any others.

4. Some thin layers of coal consist mainly of flattened layers of leaves of *Cordaites* or *Pycnophyllum*.

5. The *Stigmaria*-underclays and the stumps of *Sigillaria* in the coal-roofs equally testify to the accumulation of coal by the growth of successive forests, more especially of *Sigillariæ*. There is, on the other hand, no necessary connexion of sporangite-beds with Stigmarian soils. Such beds are more likely to be accumulated in water, and consequently to constitute bituminous shales and cannels.

6. *Lepidodendron* and its allies, to which the spore-cases in question appear to belong, are evidently much less important to coal-accumulation than *Sigillaria*, which cannot be affirmed to have produced spore-cases similar to those in question, even if the observation of Goldenberg as to their fruit can be relied on—the accuracy of which, however, I am inclined to doubt.

On the whole, then, while giving due credit to Prof. Huxley and those who have preceded him in this matter, for directing attention to this curious and, no doubt, important constituent of mineral fuel, and admitting that I may possibly have given too little attention to it, I must maintain that sporangite-beds are exceptional among coals, and that cortical and woody matters are the most abundant ingredients in all the ordinary kinds; and to this I cannot think that the coals of England constitute an exception.

It is to be observed, in conclusion, that the spore-cases of plants, in their indestructibility and richly carbonaceous character, only partake of qualities common to most suberous and epidermal matters, as I have explained in the publications already referred to. Such epidermal and cortical substances are extremely rich in carbon and hydrogen, in this resembling

bituminous coal. They are also very little liable to decay, and they resist more than other vegetable matters aqueous infiltration—properties which have caused them to remain unchanged and to resist the penetration of mineral substances more than other vegetable tissues. These qualities are well seen in the bark of our American white birch. It is no wonder that materials of this kind should constitute considerable portions of such vegetable accumulations as the beds of coal, and that, when present in large proportion, they should afford richly bituminous beds. All this agrees with the fact, apparent on examination of the common coal, that the greater number of its purest layers consist of the flattened bark of *Sigillaria* and similar trees, just as any single flattened trunk imbedded in shale becomes a layer of pure coal. It also agrees with the fact that other layers of coal, and also the cannels and earthy bitumens, appear, under the microscope, to consist of finely comminuted particles, principally of epidermal tissues, not only from the fruits and spore-cases of plants, but also from their leaves and stems. The same considerations impress us, just as much as the abundance of spore-cases, with the immense amount of the vegetable matter which has perished, during the accumulation of coal, in comparison with that which has been preserved.

I am indebted to Dr. T. Sterry Hunt for the following very valuable information, which at once places in a clear and precise light the chemical relations of epidermal tissue and spores with coal. Dr. Hunt says:—

"The outer bark of the cork-tree and the cuticle of many, if not all, other plants consists of a highly carbonaceous matter, to which the name of *suberin* has been given. The spores of *Lycopodium* also approach to this substance in composition, as will be seen by the following, one of two analyses by Duconi*, along with which I give the theoretical composition of pure cellulose or woody fibre, according to Payen and Mitscherlich, and an analysis of the suberin of cork, from *Quercus suber*, from which the ash and 2·5 per cent. of cellulose have been deducted†.

	Cellulose.	Cork.	Lycopodium.
Carbon	44·44	65·73	64·80
Hydrogen	6·17	8·33	8·73
Nitrogen	....	1·50	6·18
Oxygen	49·39	24·44	20·29
	100·00	100·00	100·00

"This difference is not less striking when we reduce the above centesimal analyses to correspond with the formula of

* Liebig & Kopp, Jahrbuch, 1847–48. † Gmelin, Handb. xv. 145.

cellulose ($C_{24}H_{20}O_{20}$), and represent cork and *Lycopodium* as containing 24 equivalents of carbon. For comparison, I give the composition of specimens of peat, brown coal, lignite, and bituminous coal*.

Cellulose	$C_{24}H_{20}O_{20}$
Cork	$C_{24}H_{18\frac{2}{10}}O_{6\frac{7}{10}}$
Lycopodium	$C_{24}H_{19\frac{4}{10}}NO_{5\frac{6}{10}}$
Peat (Vaux)	$C_{24}H_{14\frac{4}{10}}O_{10}$
Brown coal (Schrötter)	$C_{24}H_{14\frac{3}{10}}O_{10\frac{6}{10}}$
Lignite (Vaux)	$C_{24}H_{11\frac{3}{10}}O_{6\frac{4}{10}}$
Bituminous coal (Regnault)	$C_{24}H_{10}O_{3\frac{3}{10}}$

"It will be seen from this comparison that, in ultimate composition, cork and *Lycopodium* are nearer to lignite than to woody fibre, and may be converted into coal with far less loss of carbon and hydrogen than the latter. They, in fact, approach closer in composition to resins and fats than to wood, and, moreover, like those substances, repel water, with which they are not easily moistened, and thus are able to resist those atmospheric influences which effect the decay of woody tissue."

I would add to this only one further consideration. The nitrogen present in the *Lycopodium*-spores, no doubt, belongs to the protoplasm contained in them, a substance which would soon perish by decay; and, subtracting this, the cell-walls of the spores and the walls of the spore-cases would be most suitable material for the production of bituminous coal. But this suitableness they share with the epidermal tissue of the scales of strobiles, and of the stems and leaves of ferns and Lycopods, and, above all, with the thick corky envelope of the stems of *Sigillariæ* and similar trees, which, as I have elsewhere shown†, from its condition in the prostrate and erect trunks contained in the beds associated with coal, must have been highly carbonaceous and extremely enduring and impermeable to water. In short, if, instead of "spore-cases," we read "epidermal tissues in general, including spore-cases," all that Huxley has affirmed will be strictly and literally true, and in accordance with the chemical composition, microscopical characters, and mode of occurrence of coal. It will also be in accordance with the following statement, which I may be pardoned for quoting from my paper on the "Structures in Coal," published in 1859:—

"A single trunk of *Sigillaria* in an erect forest presents an

* Canadian Naturalist, vi. 253.

† "Vegetable Structures in Coal," Journ. Geol. Soc. xv. 626; "Conditions of Accumulation of Coal," *ib.* xxii. 95; Acadian Geology, 197, 464.

epitome of a coal-seam: its roots represent the *Stigmaria*-underclay; its bark the compact coal; its woody axis the mineral charcoal; its fallen leaves (and fruits), with remains of herbaceous plants growing in its shade, mixed with a little earthy matter, the layers of coarse coal. The condition of the durable outer bark of erect trees concurs with the chemical theory of coal, in showing the especial suitableness of this kind of tissue for the production of the purer compact coals. It is also probable that the comparative impermeability of the bark to mineral infiltration is of importance in this respect, enabling this material to remain unaffected by causes which have filled those layers consisting of herbaceous materials and decayed wood with pyrites and other mineral substances."

XLI.—*On the Limits and Classification of the Ganoids.* By Dr. C. Lütken*.

In my memoir on the limits and classification of the Ganoïdei (Om Ganoidernes Begrændsning og Indeling, Copenhagen, 1869) my only object was to summarize and expound the results at which science has arrived with regard to the important question above indicated; and its importance, whatever this may be, is due solely to the necessarily restricted number of those who have had the time, patience, and leisure to become thoroughly acquainted with these results by their own investigations. Certainly the history of palæichthyology shows very plainly that hitherto this question has not been perfectly clear, in part because several of the most eminent authors have, unfortunately, been unable to obtain an exact knowledge of the works of their predecessors. Hence, at least in part, arises the uncertainty as to the definition and limits of the Ganoïdei, the rank which they should occupy in the zoological scale, the mode of subdividing them, &c. Have we not seen Andreas Wagner, whose memoirs on the fishes of the Lithographic Limestone constitute one of the greatest triumphs of palæichthyology, contenting himself with a definition applicable only to a particular formation? and Rodolph Kner, the learned describer of the fishes of ancient and recent times, expressing the opinion that, at bottom, there are no Ganoids at all, and that the forms united under this name are nothing but the prototypes of the different existing ichthyological families, having nothing in common but a character of antiquity? England and southern Germany have been the prin-

* Translated by W. S. Dallas, F.L.S., from the 'Bibliothèque Universelle,' March 15, 1871, Arch. des Sci. pp. 283–296.